IN THE UNITED STATES DISTRICT COURT

FOR THE DISTRICT OF OREGON

FEREYDUN TABAIAN and AHMAD ASHRAFZADEH, Plaintiffs,	No. 3:18-cv-00326-HZ
vs.	June 19, 2019
INTEL CORPORATION, Defendant.	Portland, Oregon

TECHNOLOGY TUTORIAL

TRANSCRIPT OF PROCEEDINGS

BEFORE THE HONORABLE MARCO A. HERNANDEZ

UNITED STATES DISTRICT COURT JUDGE

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P R O C E E D I N G S

THE CLERK: Your Honor, we're here today for a technology tutorial in the matter of Tabaian, at al. versus Intel Corporation, Case No. 3:18-cv-326-HZ.

Counsel, please state your appearances for the record, starting with plaintiffs.

MR. JEFFREY LOVE: Jeff Love, Your Honor, Klarquist Sparkman.

MR. CLOSE: Howard Close with Wright Close & Barger in Houston Texas, Your Honor.

THE COURT: Good afternoon.

MR. CLOSE: I can introduce my other --

THE COURT: Sure. Whatever you want, whatever makes you happy.

MR. CLOSE: I've got, from my office, Ronnie Flack -- you've heard these names on the phone, I'm sure -- and Patrick McAndrew; and my partner, Russ Holleneck. And then my co-counsel from Texas, I have Mr. Luke Motley.

I have my client -- one of my clients here, Mr. Ashrafzadeh, who is right here (indicating).

And then we have some folks from Klarquist: Jeff, of course, and Mr. Jimmy DeRouin.

And then Dr. Majid Sarrafzadeh is going to be presenting our tutorial.

THE COURT: Okay. Great.

MS. ROTHAUGE: Good afternoon. Renee Rothauge with Markowitz Herbold.

And it's my pleasure to introduce Michael Summersgill, who you've heard on the phone, and he will introduce our team.

THE COURT: Thank you.

MR. SUMMERSGILL: Good afternoon, Your Honor.

Grant Rowan is a partner at Wilmer Hale, and he'll be presenting our tutorial today.

And then over here, Kim Schmitt is the director of patent litigation at Intel; Mashood Rassam, who is associate general counsel at Intel; and then Todd Zubler and Jordan Hirsch, both of Wilmer Hale. They'll both be arguing part of the claim construction hearing tomorrow, Your Honor.

THE COURT: That's a lot of lawyers.

Welcome, to all of you. Let's get down to business on the tutorial. I'm ready to roll.

Are these the same slides that were submitted previously?

DR. SARRAFZADEH: They are, Your Honor.

THE COURT: All right.

DR. SARRAFZADEH: Good afternoon.

My goal today here is to cover some of the circuit fundamentals that you see in the '944 patent. I'm showing the abstract and title of the patent on this page. Some of the

terms that are covered today are fundamental terms such as "circuit," "power," "droop," "programmable," "droop loss compensation." And these are the terms that we see on the title of the patent, the '944 patent, in the abstract, and throughout the patent itself. These are many of the concepts that I teach or have been teaching for the past 32 years to my students at UCLA and Northwestern University.

I have organized the tutorial today in six sections. First, I will cover some of the background on microprocessor design. Then I will get into some of the basics and fundamentals on design and analysis of circuits. We'll follow that with a very important concept called voltage regulators. We'll spend some time on that. I will then talk about two fundamental classes of circuit design: one-phase design and multiphase design.

There is an important notion here that's called calibration. I would like to spend some time to discuss that and what calibration means and how one does calibration in the context of circuit design.

Finally, at the end, I'll bring everything together to show how the whole thing works together, how voltage regulators work with microprocessors and the rest of the system.

So let me begin by background on microprocessors. Microprocessors, other names that you may hear today or

throughout this case are processors or central processing units or CPUs. They are very complex, and at the same time they are very powerful. I can do Photoshop with these microprocessors. I can or somebody can play very sophisticated video games with them. We can do very complex computation, including, but not limited to, accounting computation, so very powerful systems.

And a picture of them is shown on the right here. It's a top view of a microprocessor. Each color represents a different part of a microprocessor that has a particular task.

At the same time these microprocessors are super delicate, so we have to take care in designing them, making sure everything goes well. And we have to make sure that during operation and during manufacturing, everything goes exactly as planned.

So one of the concepts that you're going to hear in my tutorial is the notion of voltage regulation. Voltage regulation plays a fundamental role in making sure the processors operate well throughout their lifetime.

Today I will cover the notion of voltage regulators. I will show how they are designed and how do they work with the rest of the system to make them work and how do they indeed, quote, unquote, regulate the voltage.

A typical microprocessor, a high-end microprocessor, consists of billions of transistors. Transistors are simply

switches, the kind of switch that we see on the wall, that we turn this light on and off with. We have a billion of them. Transistors are responsible for computation. They do addition, multiplication, Photoshop, video rendering, so on and so forth.

We also have billions of wires. Wires are responsible for communication. They allow information to go from one transistor to the next. Again, you have billions of wires.

To the right I'm showing a very small cross-section of a microprocessor. Each vertical blue rectangle is a wire. Every time we have a rectangle on top of a green rectangle, that's how we form a transistor. So here I'm showing 10, 12 or so transistors and wires. And in reality, in a typical microprocessor we would have a billion of them, so quite complex.

On the lower left I'm showing a bunch of wires, the type of wires that maybe you see at Home Depot. There are a hundred, 200 of them or so that I'm showing here. As one could imagine, if you want to wire a building using those hundred or so wires, that's quite complex. If I switch two of them, nothing works. Fuses blow out, the light doesn't work, the air conditioning doesn't work. And this is only for a few hundred wires.

Imagine, if you would, we have a billion of these

wires and transistors in a typical microprocessor. So things could go wrong, and it's the responsibility -- the responsibility of an electrical engineer to make sure that does not happen.

And just to provide another example, I'm showing a pin sort of in the middle of the slide. We can put a hundred million transistors on the head of a pin. Again, this shows that transistors and wires are very small and therefore extremely delicate.

Where are these microprocessors used? All over. Microprocessors are used everywhere, almost everywhere, in every electronic system these days. A laptop would use it, as I've shown it here. A desktop PC would use that. A cell phone would use it. Various systems that do heart rate monitoring, like the watch that I've shown, would use a microprocessor.

About 20 years ago I was in (indiscernible), Schaumberg, Illinois. I designed one of the first digital cameras. And our job then was to design a microprocessor that goes in this tiny digital cameras. So they are everywhere.

Things that we need to take care of in designing the microprocessor is the speed. We have to make sure the microprocessors are fast. No one would buy a slow microprocessor.

We have to make sure that they don't consume too much

power. If someone advertised that I have the best cell phone, but it consumes too much power, you'll have to charge it every hour or so, or even five times a day, no one would be interested in that. So power is extremely important in design of the microprocessor.

And, last, but certainly not least, is the reliability. Reliability in design of microprocessor is quite important. If I have the fastest and the least power microprocessor, but it's not reliable, no one would be interested in it. If somebody sells me my dream car that's extremely low cost and has a good gas mileage and all that, but they say it's not reliable, the brake doesn't work every now and then, I would absolutely not buy that. I would not put my family in that car. So reliability is extremely important in design of a microprocessor.

So we have a very narrow range of operating voltage. The voltage cannot seem too much when you design a microprocessor, a CPU. So we have to take care of the voltage. We have to control it. Otherwise, it's not going to be reliable, it's not going to be fast, and it consumes too much power.

So a thing that you're going to see throughout my tutorial are in fact these three parameters -- speed, power, and reliability -- and, of course, other parameters that an engineer would take into consideration.

There are two types of variations in designing the microprocessor. One is at the factory. When they are manufacturing, there are variations.

I remember this story that, oh, about 20-some years ago in a chip factory in Japan, they realized that every day at 10:00 the quality of chips, microprocessors, are not good, exactly at 10:00. So every everyone started investigating that.

After months of investigation, they learned somewhere 10 miles away from the factory there is a train, a high-speed train, that passes every day at 10:00. That little variation caused a lot of malfunction and lower quality microprocessors. So little things that happens in microprocessor design will cause variation.

In fact, the U.S. Department of Transportation, in September of 2012, published a 248-page report that says one of the things everyone needs to take care of when they plan for high-speed trains is where is the closest chip manufacturer? And they got to account for that. They call that a high-sensitive area of concentration.

The other thing that we need to take care of is customer use variation. A customer may use a lot of Photoshop. That will make the transistors switch on and off a lot, and that heats up the microprocessor. That could potentially make it slow, make it consume a lot of power and,

at the end, make it unreliable.

So the two fundamental sources of variation are -- is one at the manufacturing site and one when the processor is already in a system, in a laptop, in a desktop, and somebody is using it.

Next I would like to spend a little bit of time discussing some fundamentals of circuit design. Here I'm showing a simple circuit, the type of circuit that we teach our undergraduate students at UCLA.

A simple circuit consists of a power supply. It could be the plug, the socket on the wall, or it could be a battery. Here I'm demonstrating an 8-volt battery as a power supply.

We have wires that are shown in color purple, in horizontal and vertical shapes.

And we have a light bulb that we call a load. A load could be anything. It could be a dishwasher, could be a toaster oven or could be a microprocessor or could be part of a microprocessor.

THE COURT: So when you use the term "load," it is always going to be something that is consuming energy?

DR. SARRAFZADEH: That's exactly right. And it consumes energy to make it power up. If it doesn't consume energy, the lights will not be powered up. That's exactly correct.

So the three fundamental concepts in design of a fundamental circuit is power supply, wire, and load.

Going to the next slide, there is actually a relationship, a very basic relationship, called ohms law, o-h-m, which says V is equal to IR; voltage is equal to I, current, times resistance.

For example, if I have an 8-volt battery and I know my load -- in this case, a light bulb -- consumes 2 ohms of resistance, then the current must be 4, because 8 is equal to 4 times 2.

When designers design a system, they don't use the picture of a light bulb or a microprocessor or a dishwasher. They use an abstract model that I've tried to demonstrate at the lower left side of the slide. The abstract in the abstract model will show the voltage source as a circle with plus and minus in it. We put a V next to it which shows the voltage. For example, we would write 5 volts. That means the voltage is 5, or it's 8.

All the wires are shown typically, but not always, as horizontal and vertical. We could also show it as curves, but typically horizontal and vertical. And we show the flow of current through the wires with an arrow. And then, finally, this figure of a zig-zag line with an R next to it is to represent the load.

So what will happen in design of a circuit is voltage

pushes the electrons out of it, out of the source. The electrons go around the circuit until they hit the load. In this example they light up the load and they go back to the other side of the voltage supply. So the current flows through the circuit all the time unless I somehow turn it off or disconnect one of the wires.

In addition to a microprocessor that I'm showing on the next slide, we may have a bigger system. A bigger system could be an example of a motherboard that has other things in it.

In fact, here in front of me I have a motherboard. With your permission, I would like to approach and show you this or hand it to you.

THE COURT: Sure.

DR. SARRAFZADEH: I appreciate that (handing).

Thank you.

THE CLERK: (Handing).

DR. SARRAFZADEH: So the big rectangle that you see there in the middle, that's a microprocessor. There are a lot of connectors. There are other circuits that you see in there.

So the thing in front of you, we'll call it a system. It's bigger than a microprocessor. So when we typically refer in engineering design to a system, it's something bigger than that. So if you open one of our desktops, we will see

something very similar that's inside it. We could pull it out and look at all the ingredients of it.

We may have -- instead of one microprocessor, we may have a set of cores. So in this example, I'm showing four cores. The processor that you have in the motherboard in front of you had two cores in it. So this has four cores. Each core is a CPU. Each core can -- the cores can work independently to work on different part of a problem -- for example, Photoshop or video rendering -- or each of them could be doing different things. So the cores are working parallel. One core could do a computation on a tax return. The other core can do Photoshop, all at the same time.

In the next slide I'm showing the abstract model that we've seen before. Instead of a load, I'm showing a very specific kind of load called the processor or CPU, and I'm also showing in a rectangle in a peach color what I call a -- what we call a voltage regulator.

So what a voltage regulator does, it's responsible to make sure the right voltage gets to the processor. If I have plugged the system that you have in front of you to a wall socket, I have 120 volts coming in. The voltage regulator, the peach block, is responsible to convert that into 5 volts. Throughout this tutorial, as an example, I will assume the processor receives only 5 volts. So the voltage regulator is responsible for that.

Also, if there are variations in the voltage -- you have seen some source of variations and you'll see more of it today. If there are slight variations, a .1 variation in the voltage, the voltage regulator is responsible to go and fix that. Otherwise, the microprocessor becomes slow, consumes too much power, and at the end of the day becomes unreliable, something that absolutely is not acceptable to the user of a microprocessor.

If, in fact, we look at the next slide, we see on the top of the picture a processor that's working under normal conditions. At the bottom we see a processor that is heating up because someone has been doing too much with it, doing too much -- two Photoshop and one video game and a number of number crunching. It heats up. Now it's the job of the voltage regulator to go adjust the voltage to make sure the right voltage gets to the processor, the 5 volts that was ideal to begin with.

So there are a number of reasons for variation in voltage; and one of them, one of the fundamental ones, once somebody is using the microprocessor, is the temperature. The temperature could be environmental temperature. The environment may be hot. But more often it's because it's being used too much. If somebody has been at their laptop for 10 hours doing all sorts of things, the microprocessor will for sure heat up. And the voltage regulator is responsible to

adjust -- to account and to adjust for that.

So next slide I'm just showing two examples. On the left is somebody who is not a heavy user of their laptop or desktop; they are just doing a few Google searches and the like. On the right is somebody who is using Photoshop and rendering of videos and images and everything else; and, therefore, obviously that processor will heat up. The voltage regulator comes in to make the necessary adjustment.

Next concept is the concept of voltage regulation. Because it's such an important piece of the design, because it's responsible to ensuring the speed is exactly where we want it to be, the power is low as we expect it, and the entire system is reliable, the voltage regulator needs to be discussed a bit further.

Here we see a triangle called an operational amplifier, a gray triangle. It has two inputs, one on the minus and one on the plus side. What an operational amplifier does or its functionality is really doing the differencing. It looks at the difference between the two inputs that it gets and it tries to minimize that difference.

There is a clever design technique where you can take the output of this triangle, the output of the amplifier, bring it back in. We say that's a feedback loop, shown in black vertical and horizontal lines, not the purple ones, only the black ones. That's a feedback loop.

What the feedback loop does is it makes sure that the output is equal to a reference voltage. What is a reference voltage? That 5 volts that the microprocessor wanted to receive and desired to receive, that's the reference voltage.

So any time, for example, due to temperature or due to manufacturing variation, that the output is not what it is supposed to do, this feedback loop makes sure the reference voltage gets to the load. That's the zig-zag line all the way to the right, which could be the microprocessor.

This is a very important design concept that allows the voltage to all get adjusted automatically so the right voltage gets to the load.

THE COURT: Let me interrupt you for just a second to make sure I'm understanding.

DR. SARRAFZADEH: Please do.

THE COURT: The feedback loop is giving information to the operational amplifier; and that information, and perhaps some other information from the reference, are helping the operational amplifier to make sure that 5 volts is going back out?

DR. SARRAFZADEH: That's precisely what it does. Exactly.

THE COURT: Thank you.

DR. SARRAFZADEH: My pleasure.

And so here we are controlling the voltage. When we talked about ohms law, V equal to IR, there is another parameter, and that's current.

So what we can do is we can also put a feedback loop to control the current, shown in the color purple. So this feedback loop does -- controls certain operations that we call modulation, and it ensures that the right current gets out.

So as I've mentioned on this slide, this current feedback is good for safety. It makes sure the current is not more than it's supposed to do, and in general it makes sure the right current gets to the load.

So now you are dealing with two parameters: voltage and current. And through these feedback loops, we can control them both. And having control over a design is extremely important.

THE COURT: So tell me the difference between -- you're using the words "current" and "voltage." What's the difference with between those two things?

DR. SARRAFZADEH: Sure.

Voltage is, for example, the 5 volts. If that fluctuates and 5.2 is getting out, this feedback loop makes sure that it goes back to 5. And the current, if it's two and a half amps and that's more than the limit, we want to bring it back down to 2; the current feedback makes sure we get that to the load.

So it deals with both parameters of the design.

THE COURT: Okay.

DR. SARRAFZADEH: If we look at the next slide, I'm showing again an example of the motherboard you have in front of you. The voltage regulator could be completely outside of the processor, as shown on the left, or as I show on the right, the voltage regulator, the two feedback loops, and other circuits that are associated with voltage regulation, part of it is outside the processor and part of it is inside.

So this notion of feedback loops, of voltage and current, works equally well on the left picture as on the right picture. It's not designed for one or the other. It's more versatile than that.

THE COURT: Is current always going to be discussed in terms of amperage, as opposed to some other term?

DR. SARRAFZADEH: Usually the national standard for current is amperage.

THE COURT: Okay.

DR. SARRAFZADEH: So it's either amperage or milliamperage or microamperage, but that's the unit of measure.

THE COURT: All right.

DR. SARRAFZADEH: Same thing for voltage. Almost always voltage is what's used as a standard. And resistance, we use ohms. Those are the standards.

THE COURT: Oh, resistance is always measured in terms of ohms?

DR. SARRAFZADEH: That's correct.

THE COURT: Okay. Thanks.

DR. SARRAFZADEH: Sure.

A term that you're going to see in the patent, in the '944 patent, is the term "droop," d-r-o-o-p. Droop is a voltage change.

Another term that you see in the title of the patent and elsewhere is the notion of "droop loss compensation." So droop loss compensation, it accounts for up and down of voltage from its desired value. So if it goes up like .2 volts, droop loss compensation accounts and compensates for that. And if it's 4.8 volts, again, droop loss compensation accounts and compensates for that.

Another term that you see is "droop function," in the next slide. That's really automatically lowering the output voltage based on the output current. It's a relationship between voltage and current, which could be a linear relationship. And the reason for that is to avoid high voltage variation.

I would like to point out that not every voltage regulator has or implements a droop function. It's simply a design choice.

THE COURT: Those terms are looking a little bit

funny to me, because it says it "automatically lowers the output voltage based on the output current."

So "current," you said, was a synonym for "amperage".

DR. SARRAFZADEH: Current, exactly.

So there is a relationship between current and voltage; for example, through ohms law. So it looks at the current, it knows voltage is related to current, and it tries to adjust one based on the other.

THE COURT: And that information is going to go to the regulator based on information on both voltage and amperage.

DR. SARRAFZADEH: That's exactly right.

THE COURT: Okay.

DR. SARRAFZADEH: Precisely.

THE COURT: Thank you.

DR. SARRAFZADEH: My pleasure.

And, again, it is an option. You could implement a droop function or you could not. It's simply a design choice.

THE COURT: Okay.

DR. SARRAFZADEH: Before we proceed, I would like to discuss two types of design. One is called the one-phase design, and the other one is called the multiphase design.

In a one-phase design, we have one of these voltage feedbacks shown in the box with the color peach, and we see also this current feedback. We have one of each. They both

start to work, and I've tried to demonstrate that with a stopwatch, with that imaginary stopwatch, where the red area shows that they are both working almost all the time. They take a little break. Then they go to work again.

This is called the one-phase design, because we have only one of each. The nice thing about one-phase design is that it's very simple, because it's only one.

And always, when I teach that, I tell the folks that it's similar to one person running a track. It's only one person. I don't need to be responsible for anybody else. I just go around the track. I run. It's all me. I'm responsible for everything.

If you go to the next slide, now we see three of these current feedbacks. This is called the multiphase design. In this example, it's a three-phase design.

So the first phase, the top one, the first purple box does one-third of the work as, again, I tried to demonstrate with that stopwatch doing one-third of the work, shown in red color. Then it takes a break, the first one. The second one gets to work, and it does the second third of the work while the other two are resting. And, finally, the last one does the last piece of the work; the first two are resting.

And it goes into a loop. Then it's the first one, second one, third one, so on and so forth. It's like relay

running. The first person runs one-third of the track, takes a break; the second person does the other third of the track; and the last person does the other third. And the advantage of that is no one gets super tired because they each have run one-third of the way.

So the advantage of a multiphase design is it's faster, it has a faster response time, and it's power efficient, whereas with one-phase design, the advantage is it's simple, so controlling it becomes simpler.

One thing that we need to be careful in design of a multiphase system is to make sure the current is balanced, everyone gets roughly one-third of the work. We cannot give the first one 90 percent of the work and the other two 5 percent each. They all got to do about one-third. And there are systems and circuits that ensures that.

So the voltage regulator that we discussed and the current feedback that we discussed, they work equally well with a one-phase design system and with a multiphase design system; in this example, a three-phase design system.

THE COURT: Okay.

DR. SARRAFZADEH: The next topic that I like to discuss is the notion of calibration. We see calibration in many experiences in everyday life.

When I go and buy a weight scale, when I bring it home, it's not zeroed out. It shows the weight -- nobody is

standing on it -- usually at two pounds or minus two pounds. Fortunately there is a knob. I take that knob and I adjust it to be zero so it doesn't show my weight more than it needs to be. If I take that weight scale from the first floor to the second floor, again I need to do this task, I need to zero it out. This process is called calibration.

So the reason for calibration is two. One is there are variations, as we discussed, when we manufacture each part, when we manufacture each CPU, because of the train that's running 10 miles away or because of chemical composition of material being a little bit off that day or the machine that makes the processor from one side to the other might have a slight variation. These will all cause variation at the manufacturing site. We need to calibrate for that, and I'll discuss how to do that.

Another place that we do calibration is called dynamic calibration or adjustment. If somebody is using their laptop or desktop through a number of Photoshop and renderings, the processor will heat up because it's been used for the past 10 hours or so. So we need to calibrate for that.

So there are two types of calibration. And I will demonstrate how to account for each of them and how to fix variations and the lack of (indiscernible) that goes with the variation.

So on the left I'm showing a processor that has been manufactured and, because of variation, it doesn't have the desired voltage. So we do a calibration there to fix it. I'll show you how to fix that. Or as we are using the system, the processor heats up, shown with the red aura around the processor. We need to fix that as well. Both of these are called calibration. One is called a static adjustment or a static calibration. One is called dynamic or in-use calibration.

So during manufacturing, normally, maybe I need -- I inspect each processor, and half of them are bad because something went wrong in manufacturing. So normally I would throw them out. That will increase the profit per part because I'm getting rid of half of them, I trash them, whereas if I can adjust for that and fix it, the profit per part increases. If I can only throw 10 percent of them and calibrate the remaining 40 percent, so now I have 90 percent of the parts working properly, that's ideal.

So that's really what manufacturing variation and the calibration associated with it does.

Next thing is customer use variation. Again, if the customer is using a system a lot, it starts getting slow, it consumes a lot of power, it becomes unreliable. But if I can realize that and adjust for it, again, I would maximize the performance of a given spec, making sure the system is

reliable, system is fast, system consumes the least amount of power that it can use.

So doing calibration to account for manufacturing variation and for customer use variation is really important.

Next what I would like to do is to bring all the concepts that I discussed today and put them next to each other and show how the whole thing works. How do we do manufacturing base calibration? How do we do customer use base calibration? Where do voltage regulators fit in, and how do they adjust for the voltage? We now have all the ingredients of bringing all that together and making it work. That's what I will cover in the next set of slides.

Circuit designers, instead of drawing every little piece of a circuit, all the gates and all the resistors, sometimes they express their design as a block. We call them a circuit block.

A circuit block, in this example, has one input line showing an arrow, and I could receive many inputs from that line. I could receive many images through that line. And it has one output line; in this case, one wire. And I could receive many outputs through that wire, many images, many pictures, many numbers through that line. So a typical circuit block has inputs and outputs as shown. We call that a block diagram.

Some examples of a block diagram is going to be a

control block. A control block controls many aspects of a circuit. It decides where to read things, what time to read things, where to get the data from. They make a lot of decisions, very similar to an air traffic controller. An air traffic controller decides which plane to land, what time to land, how much time do we need between the plane landings, so on and so forth. And, therefore, they ensure a safe operation of all the planes throughout the day. They are a controller. That's what the control block does.

We may have a memory block. Memory block is where we store things.

We may have a voltage regulator block. A voltage regulator block is, of course, very important. They get their own block because they are important, because they are responsible for voltage variation and fixing that, as we discussed.

And, finally, we may have load blocks. That's where the microprocessors or a core of a microprocessor would reside. And, of course, we may have many other types of blocks.

So when one sees a typical electronic engineering design, you will see transistors and all that. You may also see these rectangles that are really blocks, each of which have a certain task that they perform.

One of the blocks that is used quite frequently in

design are memory blocks, and there are really two types of them. One is called the volatile memory, and the other one is called nonvolatile memory.

With volatile memory, if I turn off the system, if I turn off my laptop, all the data is lost. So next time I turn my laptop on, anything involved in the memory is gone. In nonvolatile memory, if I turn the system off and on again, all the data is going to remain in the memory.

So, in summary, volatile memory requires power. Nonvolatile memory doesn't require power, but it's more expensive to build and maintain. And for that matter, I typically or we don't typically, have too many nonvolatile memory. They're really scarce. There are just a few of them here and there, whereas volatile memory, they are everywhere. They are very low cost. They are very fast. Volatile memory are faster. So things that I want to do on the fly realtime, I put that information typically in volatile memory.

When I teach this concept to my classes, I typically tell them, think of nonvolatile memory as a safe in your house. You put only very important things in the safe in your house. I personally put my passport there and birth certificates of myself and my family, and usually not much more, whereas things such as plates and forks and knives, I put in other cabinets. You could think of them as volatile memory. I need to quickly be able to access them. I do not

need to put too much stuff in nonvolatile memory, in the safe. So there are these two types of memory elements.

Now I would like to, if I could, walk you through the process of calibration. So we already covered that there are manufacturing variations at the manufacturer's site. We can program these parts in nonvolatile memory to realize what kind of voltage they need based on the variation they have, based on the vibration that they had during manufacturing, based on variation in chemical composition that makes up the transistors and the wires.

So in the first processor, let's assume that's perfect. Processor 1 is exactly according to spec. I put, for example, five zeros and five ones to indicate that. And I put that in the nonvolatile memory, because these parts get shipped in a laptop or desktop, and that's normally off. And the next time I turn it on, I want to know what those values were. I don't want them to be gone.

Processor 2, on the other hand, maybe is getting too much voltage naturally. So, again, I program that part, that processor No. 2, through nonvolatile memory to remember that, so when I'm using it in operation, I remember that I need, instead of 5 volts, to provide 4.8 volts to processor 2.

Same thing in processor 3. Maybe I remember that I need to give it more voltage, 5.2, for example. I remember that, and I program the part, processor 3 part, to remember

that I need to provide more voltage to it.

So I can account for manufacturing variations by programming these parts at the manufacturer. So now that I ship them with my cell phone or with my digital camera or with my variable watch, these are already programmed in and remember it.

So the processor and the corresponding device programmability that accounted for manufacturing variation is put into a desktop in the example that I'm showing here. The user is now using it, is doing his or her Photoshop and other types of number crunching.

The calibration control block now takes charge. Remember, these control blocks do a lot of management and planning of who does what when.

So the calibration control blocks remembers this programming of the devices. Then it says a temperature sensor. I'm showing a thermometer. Of course, a typical sensor is much, much smaller. It's tiny and typically inside a microprocessor. You may have one or more of them. Pictorially, I'm showing it as sort of a thermometer. It's not that. It's much smaller than that.

So this temperature sensor keeps track of the temperature throughout the processor. Then what it does is when the processor heats up because it's being used a lot, because I'm doing Photoshop and heavy number crunching, the

temperature sensor remembers that. It works with the calibration control block.

The calibration control block takes that information about realtime use of the system, that this person right now is using -- is a heavy user of the processor, of the laptop, right now. Let's remember that. Let's write that information, for example, in volatile memory. And let's dictate -- starting from control block, let's dictate to the voltage regulator to go and fix things, to provide, for example, the right voltage.

And when it does, everything comes down. 5 volts gets to the processor again, and everything will resume with its normal operation. The processor will have the desired speed, will have the desired power consumption, and it's going to be reliable again.

If we look at the title of the patent, "Programmable Calibration Circuit for Power Supply Current Sensing and Droop Loss Compensation," we have really covered all of that.

Programmability is when we write in nonvolatile memory and, for example, in volatile memory to adjust and to account and compensate for manufacturing variation and in-use variation.

Calibration circuit is the controller shown in green. That controls things. It decides when the voltage regulator does what. It reads information, for example, from

nonvolatile memory.

And, of course, the concept here is power supply where we do current sensing shown in purple box. That's the feedback loop and the modulation concept that we discussed and droop loss compensation, meaning variation in voltage.

So putting everything that we have just put together or designed together today in this tutorial, we can make the whole thing work.

THE COURT: Is the calibration control block, as written in the patent, in your opinion, part of the voltage regulator or is it something that's contained outside of the voltage regulator?

DR. SARRAFZADEH: It is outside of it. Indeed, if we look at Claim 1, it says, "A circuit comprising a regulator circuit and a calibration control circuit." And it talks about how they interface with each other, which I'm going to go over that right now.

THE COURT: Okay.

DR. SARRAFZADEH: So it become clear that they are separate, but they communicate with each other.

THE COURT: Okay.

DR. SARRAFZADEH: So now, in fact, going to the Claim 1 as an example of the patent, I have drawn these boxes. They don't exist in Figure 1 of the '944 patent. I've drawn four boxes, really in order to enable communication of the

name of these blocks.

So the peach block, as I've used throughout this tutorial, is the regulator circuit block. The calibration control block is shown in color green. In the blue is the kind of circuitry that is associated with the temperature. And, finally, I have a load, which could be the microprocessor here.

So Claim 1, for example, talks about -- so I'm not going to show what is inside these blocks, because that's not what Claim 1 is talking about. For example, we see in Claim 1 the word "sense outputs." It says sense output -- and that I have highlighted in the figure to the right -- is communicated from calibration control circuit to the regulator circuit block.

THE COURT: You're getting ahead of me. Hang on a second.

DR. SARRAFZADEH: Sure, of course.

(Pause) So in this slide, I have blocked everything. I have hidden all the details of what goes in a regulator circuit. And the next slide, I have highlighted the words "sense outputs."

THE COURT: Okay.

DR. SARRAFZADEH: So sense outputs is -- as the claim says, it gets communicated between calibration control circuit and regulator circuit block. So this claim talks about the

interface and the communication between them.

Another term that we see in Claim 1 is "droop outputs," which I have highlighted in the figure in the next slide in yellow, which is, again, an interface communication between the green block and the peach block.

It talks about the load voltage input, which, again, as it says, "said calibration control circuit interfaces with said regulator circuit via" all these things, one of which is a load voltage input. So load voltage input is an interface between regulator circuit block and the calibration control circuit.

And, finally, we talk about temperature input. That's another interface from the temperature input block to calibration control circuit.

So bringing all that together, we see that Claim 1 doesn't -- focuses on the interfaces between these blocks that I have highlighted. One of ordinary skill in the art knows that there are many ways to design what goes inside of each block.

I remember about 20 years ago we started a company with one of my former student called Higher Design, hierarchical design, designing circuits. And the very first mandate that I had for my team is you have to -- when you design a block like this, like a regulator block, you have to look at all variations. And there are many of them, and there

is trade-off. One is faster. One is bigger. One consumes less power. Let's make it rigorous in looking at these design variations. That was my mandate from Day 1. That turned out to be quite powerful. Instead of just designing the first thing that you see, let's look at all variation.

I've been back to -- this company was acquired by the biggest FPGA manufacturer, called Xilinx, and my student now oversees 1200 employees. And what he tells me is that notion of variation they use rigorously as of today. The entire CAD group has been replaced by our design. And I think it's because of these trade-off mandates that we started from Day 1.

So there are many ways to design each of these blocks. There are claims -- for example, Claim 26 -- which gets into details of how these blocks are designed. For example, in Claim 26 we see the words "multiphase clock register" or we see the notion of "adjustable sense amplifier." They are discussed in Claim 26.

Claim 3, for example, is the first time we see that it talks about the notion of "multiphase regulator." In fact, Figure 1 shows a two-phase regulator.

Another thing you see in Claim 26 is the notion of "adjustable droop controller." We did not see that in Claim 1. The interfaces were discussed in Claim 1. Here the notion of "adjustable droop amplifier" is called for in

Claim 26.

In fact, there are certain ways of designing a circuit where there are no adjustable droop amplifiers. If you look at the provisional patent for this, for '944, Figure 8 -- I've shown Figure 8 here -- clearly, an adjustable droop amplifier is missing. It means there are other variations of how you can design the details of that regulator voltage, the peach block.

Another thing, Claim 1 doesn't get into detail on what is inside the temperature input block. Claim 14 does. Claim 14 says that inside the blue block, the temperature input block, we will have a temperature sensor that senses the temperature. You see that only starting in Claim 14. And we have an amplifier, the triangle that you see in the blue box.

THE COURT: Is an amplifier always something that's going to make changes?

DR. SARRAFZADEH: Yes, correct. It takes an input or multiple inputs and makes changes to them.

THE COURT: It's the thing that does the adjusting work; is that correct?

DR. SARRAFZADEH: That's correct, yes.

THE COURT: And is it the controller that tells it how to adjust?

DR. SARRAFZADEH: We see there is a line from calibration control circuit back to temperature input block,

with an arrow that goes on the side of the triangle. Yes, it is dictating certain type of how to adjust information.

THE COURT: So the controller is getting information from the temperature input block and then using that information, sending it back to the adjustable temperature amplifier, which is then making changes based on whatever the standard is, the calibration standard is.

DR. SARRAFZADEH: That's precisely what happens.

THE COURT: I don't know what I just said, but it sounded good at the time.

DR. SARRAFZADEH: It was 100 percent correct.

THE COURT: All right.

DR. SARRAFZADEH: I appreciate that.

And we see, for example, in Claim 18 the notion of an "external interface" for the first time is discussed, and that's shown in yellow highlight at the bottom of Figure 1.

If we go to Figure 2 of the patent, same thing. Claim 1 really talks about the interfaces between calibration control -- or circuit controller and everything else. It talks about sense outputs, droop outputs, load voltage inputs, and temperature input. These are the interfaces. That's what Claim 1 is concerned about. It doesn't talk about other amplifiers and other things that you see.

There are claims that dictate and focus on other things that we see in Figure 2. For example, Claim 10 says

that the "sense output comprises a digital-to-analog converter." The symbol for that is DAC that you see kind of on top of Figure 2. The rectangle, the yellow rectangle, says "DAC with register input," digital-to-analog converter with register input and an amplifier buffer. The triangle above that is an amplifier buffer.

So these are discussed in Claim 10, not, for example, in Claim 1.

THE COURT: Can you explain what a digital-to-analog converter means?

DR. SARRAFZADEH: Absolutely.

So many circuits, part of it works in digital; they deal with zeros and ones. And part of it works with analogs; these are continuous signals. So at times we need to interface or convert one to the other. So if you have digital -- zeros and ones -- and you want to translate that into a continuous signal, we use a digital-to-analog converter.

And, vice versa, if you want to take those continuous signals and translate that into zeros and ones, we use an ADC, an analog-to-digital converter.

THE COURT: But what does that mean to me, a regular guy that doesn't know very much about what you're talking about at this moment?

DR. SARRAFZADEH: Sure. Exactly.

I see people come and go from this room. I don't care about details of every step, the continuous movement that they make, whether they raise their foot, whether they put their foot down. I just want to know how many steps they take. That's digital: 0, 1, 2. Details of my movement is not relevant.

THE COURT: Okay.

DR. SARRAFZADEH: A system like Fitbit that counts how many steps I take, that make sure I hit my 10,000 steps, does that. It has analog signal. I don't understand, as a user, what that analog signal is. I only care about the number: 500, 501. Those are digital information.

THE COURT: Okay.

DR. SARRAFZADEH: And typical circuits have both digital parts and analog parts, and we need to be able to convert back and forth.

THE COURT: And in terms of this device, how are the -- what's the importance of the digital-to-analog and analog-to-digital?

DR. SARRAFZADEH: Great.

So many of the elements here -- for example, the way voltage is sent, the voltage variation, the voltage signal itself, if I look at it, that's an analog signal.

THE COURT: Okay.

DR. SARRAFZADEH: But if I want to take that

information and store it somehow in nonvolatile memory, I would convert it into digital information, because there are advantages in dealing with each of those domains. So the best of both worlds, you deal with them both simultaneously in this patent.

THE COURT: And is information always stored best if it's digital?

DR. SARRAFZADEH: Not necessarily.

THE COURT: Okay.

DR. SARRAFZADEH: But typically memory is stored as digital information, zeros and ones.

THE COURT: Okay. Thank you.

DR. SARRAFZADEH: My pleasure.

So my hope today was to cover some fundamentals of circuit design, really to enable the Court to look at the title of the abstract and the rest of the patent and some of the terms become more familiar.

And we have done exactly that today. We have covered regulation of power that you see in the first line of the abstract. We have talked about droop. We have talked about multiphase, temperature variation. We have talked about a very important concept called calibration, both due to manufacturing variation and in-use variation.

So I hope you have found my tutorial useful today.

THE COURT: Yes. Thank you very much. I appreciate

it.

DR. SARRAFZADEH: It's a pleasure.

THE COURT: Next?

MR. SUMMERSGILL: Your Honor, we're prepared to dive right in, or if you want to take a break from voltage regulation technology, we're also happy to --

THE COURT: No. Let's roll on.

MR. SUMMERSGILL: Okay.

THE COURT: I'm having a good time here.

MR. SUMMERSGILL: All right. Good.

Well, you're about to learn some more about voltage regulation technology.

As I mentioned, Grant Rowan will be doing our tutorial. He's an engineer. He got his engineering degree in 1990 from Maryland. He's a member of the patent bar. He's, of course, also a lawyer, and for the last 15 years has had the misfortune of having to teach me about all of this technology, so he's grown accustomed to it.

THE COURT: Okay. Thank you.

MR. SUMMERSGILL: And do you have a copy, a hard copy of our --

THE COURT: I do. Unless they've changed.

MR. SUMMERSGILL: They have not changed.

THE COURT: By the way, after I'm done letting the experts educate me, to the extent that they have, I will have

questions for each of the experts regarding the other expert's presentations and whether they agree or disagree with what was said.

MR. ROWAN: Okay. Great.

Good afternoon, Your Honor.

In this tutorial, as shown on slide 2, I plan on covering four topics. The first topic deals with voltage regulation. And then we'll explain a little bit about feedback loops, which are used in some but not all types of voltage regulators. And then we'll talk about a specific way of regulating voltage known as a droop function. And not all voltage regulators employ a droop function.

And then, finally, once we go through the background technology, we'll go into some details of the patent at issue in this case, which we'll refer to as the '955 [sic] patent.

So let's first talk about voltage regulators. As its name implies, a voltage regulator is an electronic device that will control or regulate the level of voltage that's supplied to other types of electronic devices.

But before we dive into the details of voltage regulation, it might be helpful to talk about some of the background technology at issue for the voltage regulators. So as shown in slide 4, all electric circuits operate using current and voltage. Current and voltage are aspects of power that help power electronic devices and help them operate.

So examples of electric circuits are the very types of many electric circuits in a laptop computer, such as your display, the processor, and so forth.

If you take a look at slide 5, current is the flow of electric charge through a circuit. So the flow of electric charge or current helps make these electric devices operate. And if you want to think about an analogy, the flow of current through a circuit is much like the flow of water through a pipe. So you can think about a conductor of an electric circuit being a pipe and the flow of current through that conductor or circuit is like the flow of water through the pipe.

On the other hand, as shown in slide 6, voltage is the electrical pressure in a circuit. This electrical pressure helps to force the current through the circuit. And, again, going back to the water pipe analogy, you can think of current being the water flowing through the pipe. The voltage is the pressure, the water pressure that helps force that water through the pipe.

And so power sources are used to supply voltage and current to the electrical circuit so that they can operate. There are many types of power sources. Common power sources are batteries or the electrical wall outlet that you plug an electrical device into to help it run.

And so in the example shown here in slide 7, we show

a battery that supplies voltage and current to the laptop computer. This battery is a direct current or DC power source and supplies a fixed level of voltage to the laptop computer. And here we show the battery supplying 4 volts to the computer.

However, while some of the components in the laptop may operate based on 4 volts, there are other components that may require a different level of voltage to operate properly.

So, for example, a processor within the laptop may operate properly if it receives 2 volts as opposed to receiving the 4 volts from the battery. So if, by mistake, the 4 volts from the battery are supplied to the processor, as shown in slide 8, the processor may not function, it may overheat, and may become damaged.

So turning to slide 9, to overcome this problem, laptops and other devices include components called voltage regulators. And, again, as their name implies, voltage regulators will regulate the voltage that's supplied to electronic devices such as the processor so those devices receive the correct level of voltage for their operation. And voltage regulators, they're not new. They've been known well before the '944 patent.

So if we turn to slide 10, slide 10 shows a simple example of how a voltage regulator operates. So, first, the voltage regulator receives a voltage from the battery of 4

volts. And this voltage is typically referred to as an input voltage or V in.

And then moving along to slide 11, the voltage regulator will then regulate the voltage or convert that 4 volts that is input from the battery into 2 volts that is the proper voltage to be used by the processor.

Then as shown in slide 12, that voltage of 2 volts is output as an output voltage to the processor. And that output voltage supplied by the voltage regulator to the processor is typically referred to as an output voltage or V out. And here we can see that the voltage regulator converted the 4 volts from the battery to the appropriate level of voltage -- namely, 2 volts -- so the output voltage could be supplied to the processor so the processor can operate correctly.

Now, the processor is the device that receives the output voltage from the voltage regulator, and this is typically referred to as the "load" in the '944 patent and in the field.

So I'd like to move on to feedback loops. Feedback loops, in some voltage regulators, help the regulators regulate the voltage.

So if we turn to slide 14, voltage regulators that use feedback loops -- feedback loops have been around. They're not new. They've been around long before the '944

patent, but some feedback loops take information regarding the output voltage and output current from the voltage regulator, and they will supply that output current and output voltage that's supplied to the load or processor and also feed that information back to the voltage regulator so that the regulator can make certain adjustments and reconfigure the levels of the voltage, for example, that it supplies to the load.

THE COURT: Is the feedback loop always going to be between the regulator and the load or can it be something that is coming off of the load itself?

MR. ROWAN: You could have a feedback loop from the load or between the regulator and the load. It depends on the design of the circuitry. You can even have certain feedback loops, for example, inside the voltage regulator itself.

THE COURT: Okay.

MR. ROWAN: But as shown in red here in slide 14, the feedback loop, here in slide 14, the voltage regulator is outputting an output voltage to the load. The red feedback loop feeds that output voltage to the load; and in addition to feeding it to the load, the red feedback loop feeds the output voltage back to the voltage regulator.

So in one example, if the voltage regulator wants to supply 2 volts to the processor, and let's say the actual voltage being supplied, because of some internal error or

something, is actually 1.9 volts, that 1.9 volts that's being supplied to the processor can be fed back to the regulator. The regulator can compare that 1.9 volts that's actually being supplied to the processor with the desired target voltage of 2 volts. And if there are any differences between those two, the voltage regulator can adjust the output voltage up by a tenth of a volt so that 2 volts are now being supplied to the processor.

THE COURT: Does the measurement of what comprises the feedback loop use energy?

MR. ROWAN: The feedback loop, yes, it will use energy.

THE COURT: A very small amount of energy, I assume.

MR. ROWAN: Just a small amount of energy, that's correct.

THE COURT: Okay. Thank you.

MR. ROWAN: So to learn more details about the feedback loop, if we go to slide 16, we can go into the inner workings of the voltage regulator. And this shows some of the feedback loops. And, in particular, the voltage regulator in slide 16 shows two types of feedback loops: a voltage feedback loop and a current feedback loop.

And I'll explain in a little more detail, but the voltage feedback loop includes the component -- if you go down along the right side of the voltage regulator, the voltage

feedback loop goes to the error amplifier, which is the triangle at the bottom of the figure, and continues around up to a triangle in the upper left portion of the figure that's known as a pulse width modulator or PWM.

This voltage regulator also includes a current feedback loop. And the current feedback loop includes a current sense circuit, which is the rectangle in the upper right corner of the figure; a sense amplifier, which is the triangle in the middle of the figure; and the pulse width modulator, which is again the PWM triangle in the upper left.

THE COURT: Your slide 16 looks completely different than my slide 16. My slide 16 just has a gray box.

So just in case you want me to have the right slide 16, I don't have it.

MR. ROWAN: Well, you know what? I'm sorry. There is an animation that transforms that gray box in slide 16 into what's shown in the figure.

THE COURT: Okay.

MR. ROWAN: I apologize, Your Honor.

So maybe this will add a little more clarity and sort of remove the mystery of the gray box, if you will.

On slide 17 we're focusing in on just the voltage feedback loop. And, again, the voltage feedback loop includes the error amplifier, the triangle at the bottom of the slide; and includes the pulse width modulator or PWM in the upper

left portion of the slide. And in the voltage feedback loop, the regulator supplies an output voltage to the load and also feeds back that output voltage to the regulator so the regulator can make further adjustments.

And so let's walk through that in a few more steps. On slide 18 the regulator supplies an output voltage to the load, as shown by the red-colored portion of the wire going from the regulator to the load on the right.

THE COURT: You lost me a little bit. Can I back you up just for a moment?

Is this whole thing the regulator or is this diagram simply showing -- where the two arrows are pointing up and down, is that where the regulator would be located in this diagram?

MR. ROWAN: So the whole -- the load is not within the regulator.

THE COURT: Okay.

MR. ROWAN: The load is on the right-hand side.

THE COURT: Correct. Okay.

MR. ROWAN: Here, the rest of the circuitry in this figure is all considered to be the regulator.

THE COURT: Thank you.

MR. ROWAN: And so the feedback loop here is actually internal to the regulator itself. But as you can see at the junction from where the red portion of the line turns black,

it is the same voltage that's being supplied to the load, it's actually being fed back to the error amplifier in the voltage regulator at the bottom of the slide.

THE COURT: Wouldn't the use of -- that the load uses regarding the voltage lower the amount of energy that is being fed back?

MR. ROWAN: So as the load consumes current, it's going to be consuming energy. And that energy is being supplied to the load from the voltage regulator.

THE COURT: Right. And so then the energy that then comes back from the load, returning to the error amplifier, would be somewhat less than what was going to the load itself?

MR. ROWAN: So the voltage regulator wants to supply, in this case, for example, 2 volts to the load.

THE COURT: Correct.

MR. ROWAN: That 2 volts is going to be applied to the load and it's going to be applied also to the error amplifier. It's the same 2 volts. But what happens is there is also current that's being supplied to the load from the voltage regulator. And so the majority of that current is going to be consumed by the load, and a small portion of that current is going to be continued around and being consumed by the error amplifier within the feedback loop.

THE COURT: Okay.

MR. ROWAN: So you are correct that the load will

consume the majority of the energy that's being provided by the voltage regulator, primarily in the form of the current. And a small portion of current is also going to continue around in the voltage feedback loop to then be consumed by the error amplifier and the other components within the voltage regulator.

THE COURT: And the use of the language that you are giving to the Court, current and voltage are two different things?

MR. ROWAN: Current and voltage are two different things. Current you can think about as the flow of water through a pipe. The voltage, you can think about that as the water pressure that pushes the water through the pipe.

THE COURT: Thank you.

MR. ROWAN: And together, the level of voltage and the level of current, in combination, dictate how much power is being provided.

THE COURT: Okay.

MR. ROWAN: So in addition to the voltage being applied, the output voltage being applied to the load, the output voltage is also fed back to the regulator, as shown in slide 19.

And, more particularly, as we've been discussing, in slide 20 this output voltage is fed to a component in the voltage feedback loop called the error amplifier. And the

error amplifier receives the actual output voltage being provided to the load.

As shown in side 21, the error amplifier also receives a reference voltage. And the reference voltage can be thought of what is the desired or target voltage that I want to supply to the load?

So the load or the processor in this example is supposed to receive 2 volts. The reference voltage may have a value of 2 volts. And so what the error amplifier does is it will receive the actual output voltage from the load. And let's say due to some internal temperature variations or what have you, it's 1.9 volts. The error amplifier will compare the actual output voltage of 1.9 volts being supplied to the load with the desired or target reference voltage in green of 2 volts; and the error amplifier is then going to create an error signal, as shown in slide 22.

And that error signal is going to represent the difference between the desired target voltage being referenced and the actual output load voltage being supplied to the load. And that error signal is going to represent that difference. And the error signal is then supplied to the pulse width modulator or PWM in the upper left portion of the figure.

And that PWM, as set forth in slide 23 and shown in gray, basically controls circuitry in blue. And those switches that are denoted -- that's the things with the upper

pointing arrow and lower pointing arrow to the right of the blue control circuitry -- and the pulse width modulator in gray and the control circuitry are going to adjust the regulator so it increases the 1.9 volts being supplied to the load so that it meets the target reference voltage of 2 volts to be supplied to the load.

THE COURT: The change from 1.9 to 2.0 in your example occurs in the circuitry to control switches?

MR. ROWAN: Yes. So the two black switches to the right of the blue control circuitry box, those switches turn on and off, much like turning on and off a light switch in the room. If you want more light in the room, you keep the light switch on longer; and if you want less light in the room, you keep the switch off for a longer period of time.

So the way these switches work is if you want to supply more voltage to the load, you turn the switches on very quickly, you turn them on and off very quickly, but you keep them on longer than you keep them off to supply more voltage to the load. If you want to supply less voltage to the load, you still turn them on and off very quickly, but you keep them off a little bit longer than you would otherwise keep them on, to supply less voltage to the load.

THE COURT: I never knew that. That's very interesting.

MR. ROWAN: So based on this voltage feedback loop,

the voltage regulator can basically determine how much voltage is actually being applied to the load, how far it is off from the desired voltage that should be supplied to the load. And it's going to change the timing, the on/off timing of these switches to then recalibrate how much voltage is being supplied to the load to bring the actual output voltage supplied to the load in line with the desired output voltage to be supplied to the load.

So if we turn to slide 24 --

THE COURT: This is a good -- it's not that I need a break, but I have some responsibility to my staff to let them have a break from time to time. So why don't we take a break for 10 minutes, and then we'll continue with your presentation.

MR. ROWAN: Of course, Your Honor. Thank you.

THE COURT: Thank you.

(A recess is then taken.)

THE COURT: Be seated.

Go ahead.

MR. ROWAN: Thank you very much, Your Honor.

So I believe we left off on slide 24, with respect to the current feedback loop.

THE COURT: Yes, sir.

MR. ROWAN: And if you take a look at slide 24, the current feedback loop includes the current sense circuit,

which is in the box in the upper right portion of the figure; the sense amplifier, which is the triangle in the middle of the figure; and the pulse width modulator that is in the upper left portion of the figure, abbreviated PWM.

And when the voltage regulator supplies current to the load, the current feedback loop measures the amount of current being supplied to the load and feeds that information back to the regulator so that the regulator can make further adjustments.

So if we go to slide 25, maybe we can break that down just a little bit.

And, Your Honor, I just realized that we do have some animations, and so some of the things I may have been talking about may have been animated on your screen.

THE COURT: Okay.

MR. ROWAN: I'll let you know when an animation is coming up, if that would be helpful for Your Honor.

THE COURT: Sure.

MR. ROWAN: So the current sense circuit, as shown in the animation, will actually measure the current that's being supplied to the load and it will output an initial measured current signal to the sense amplifier, the sense amplifier being shown in yellow.

And then, as shown in slide 26, the sense amplifier will adjust the signal. In this case, the sense amplifier may

amplify or increase the signal to create a final measured current signal to have a value that can be understood by the pulse width modulator in the upper left-hand portion of the figure.

And then the pulse width modulator, shown in gray in the animation in slide 27, will then control the circuitry in blue, which turns on and off the switches to then make adjustments.

THE COURT: So before you go on, just -- and I think I'm starting to understand this. The yellow arrows, are those measuring amperage?

MR. ROWAN: So the yellow arrows, those are measuring amps. Current is typically measured in units of amps or milliamps.

THE COURT: And at the same time, the black arrows are measuring volts.

MR. ROWAN: Yes.

So what happens, if I can dive a little more deeply into the technology, Your Honor, the black arrows are measuring the output voltage in the voltage feedback loop, and that brings that back to the voltage regulator.

THE COURT: Okay.

MR. ROWAN: The current sense circuit measures the current, which is in amps, that's being supplied to the load. However, the current sense circuit outputs a corresponding

signal that is not necessarily a current signal, but a value, a measured signal, and sends that to the sense amplifier. So it's not actually feeding back actual current itself. It's sending a signal back to the sense amplifier that says, By the way, there are 2 amps or there are 3 amps that are being supplied from this voltage regulator to the load.

THE COURT: Go ahead.

MR. ROWAN: Okay. Thank you, Your Honor.

So I'd like to now go into and explain a voltage regulation technique known as the droop function. And if we turn to slide 29, as previously explained, voltage regulators regulate voltage. Some, but not all, voltage regulators use voltage feedback loops to ensure that the output voltage, V out, coincides with a target or desired reference voltage, V ref.

The droop function is a different technique for regulating voltage. It's different than just simply using a voltage feedback loop to make the target voltage equal to the reference voltage. It's a very specific technique that actually preemptively adjusts the output voltage based on the output current being supplied to the load, to keep the output voltage within a specific range of voltages so it doesn't exceed a maximum voltage or fall below a minimum voltage.

And we'll dive in a little bit more deeply, but as we turn to slide 30, to better understand what the droop function

is, it might be helpful to go into just a little bit more background technology.

So as previously mentioned, a voltage regulator is designed to supply a particular output voltage, having a particular value to the load. In our example, our voltage regulator was supplying 2 volts as an output voltage to the processor.

In actuality, previously I said the processor needed to receive 2 volts to operate properly. In actuality, the processor can receive a range of voltage. It doesn't need to receive precisely 2 volts to operate properly. If it receives a voltage that's higher than a minimum threshold voltage and that's less than a maximum threshold voltage, if the voltage output to it is in that range, it will function properly.

So if you take a look at the graph on slide 30, you'll see a V min, which represents the minimum voltage, and a V max that represents the maximum permitted voltage that the processor can receive.

So going back to our example where the processor was receiving 2 volts to operate properly, the processor may actually be able to operate properly if it receives a voltage that's greater than one volt but that's less than three volts. Somewhere in that range it can operate okay.

And so conventional voltage regulators are designed

to output the output voltage to be at the midpoint between V max and V min. So as shown in this figure, a conventional voltage regulator without a droop function is designed to keep the output voltage, V out, to be 2 volts, which is halfway between the minimum voltage of 1 volt and the maximum voltage, V max, of 3 volts.

However, as we'll get into, simply trying to maintain that output voltage of 2 volts precisely at the midpoint between the minimum of 1 volt and the maximum of 3 volts isn't always a great technique; and trying to do so may actually cause damage to the processor. And I'll explain that momentarily.

On slide 31 the amount of current that the processor demands to operate is going to change over time. When a processor is really busy, performing a lot of mathematical calculations, crunching numbers, doing rendering of data and things like that, the processor is very busy and needs a lot of current to energize itself to run.

THE COURT: Yeah. The plaintiffs always show some kid working at a computer to demonstrate that there's a lot of stuff going on.

MR. ROWAN: The child has a lot more energy than I do at my age, Your Honor.

THE COURT: Yeah. I thought that was a good way to display that.

MR. ROWAN: So when the processor is extremely busy, demanding a lot of current, we refer to that processor as being awake, for the purposes of this tutorial.

On the other hand, when the processor is idle and not instructed to perform a lot of operations, it doesn't demand a lot of current; and we refer to the processor in that situation as being asleep.

And so what happens is over time, as you can imagine, Your Honor, is that the processor is going to transition from times it's very busy and consuming a lot of current to where it's idle and not demanding much current whatsoever.

And these fluctuations of the processor and the demand for current is going to cause the output voltage that's supplied from the regulator to the processor to also fluctuate unintentionally. And so maintaining the voltage precisely at the midpoint of 2 volts, between the minimum of 1 volt and the maximum of 3 volts, sometimes may cause those fluctuations in the output voltage to drop below the minimum voltage or increase above the maximum voltage. And we have a little bit of an animation on slide 32 that may help explain what I mean by that.

So let's use this water faucet analogy, and let's assume that the processor is sleeping. It's not demanding a lot of current. And this is analogous to the water faucet shown on the right-hand side of slide 32 as being turned off.

There is no current that's being demanded or flowing into the processor, just like there is no water that's flowing through the faucet because the faucet is off.

When the faucet is off, the water pressure inside the pipes behind the faucet is relatively high because the water has nowhere to go. And that's demonstrated by the water pressure sensor in the bottom of the figure, showing that the water pressure, when the faucet is off, is high.

So assume that the processor is sleeping. It's not demanding a lot of current. There's no water flowing through the water faucet. Then all of a sudden the processor wakes up and wants to demand a lot of current to perform a lot of operations.

As shown in the animation, that's like turning the water faucet on all of a sudden and the current is flowing to the processor. Under that situation, the pressure that had built up to be a high pressure when the water faucet was off all of a sudden decreases in pressure when the water faucet is on and the water is flowing freely.

That's much like the voltage, when the processor is sleeping, is at a certain value; and then all of a sudden, when the processor wakes up and demands current, the water is going to start to flow and the water pressure or the voltage is similarly going to drop.

On the other hand, let's assume in slide 33 that the

processor is awake and it's consuming a lot of voltage. The water is flowing -- sorry, consuming a lot of current. The water is flowing through the water faucet. In this scenario the water pressure in the pipes is relatively low, as shown by the pressure sensor in the slide.

When the processor is demanding a lot of current and is awake and then all of a sudden becomes idle and asleep and stops demanding current, that's like turning the water faucet off. When the water faucet turns off, as shown by the animation, all of a sudden, then, the pressure of the water in the pipe, as soon as the water is turned off, increases to a high value, as shown by the pressure sensor.

And so that is analogous to when the processor is awake and demanding a lot of current suddenly turns off and doesn't demand a lot of current, there's going to be an increase in voltage or voltage spike from the output of the voltage regulator.

And so let's maybe take that back to the graph that we have here and try to explain that in slide 34.

So in slide 34, let's assume the processor is sleeping, as shown in the graph, not demanding a lot of current. And the voltage regulator that does not employ a droop function is trying to maintain the voltage at the midpoint between the minimum voltage, V min, and the maximum voltage, V max.

When the processor suddenly wakes up, as shown in slide 35, that's like turning on the faucet. The current starts flowing to the processor because it becomes awake, and the water pressure in the faucet drops because the water is now flowing. That is like the voltage, the electrical pressure being output to the load suddenly dropping, as shown in the figure, to create a voltage droop. And that sudden unintentional voltage droop now falls below V min because the processor turned on, became awake, started demanding current, and the voltage then suddenly dropped unintentionally. And, as you can see, that voltage droop falls below the minimum voltage, V min, and that may cause the processor to malfunction.

On the other hand, going to slide 36, let's take the scenario where the processor is awake. The processor is demanding a lot of current. There's a lot of water flowing through the water faucet. If the processor suddenly goes to sleep and becomes idle and stops demanding the current, that's like turning the water faucet on. The water pressure for the water faucet spikes, goes up momentarily, just like the voltage that's being output from the regulator to the processor will spike up. And the voltage spike, as shown here in slide 37, now exceeds the maximum voltage, V max.

And when the voltage momentarily spikes up and the processor goes from being awake to being asleep and that

voltage spike exceeds the maximum permitted voltage, it can cause the processor to malfunction, and it can even cause damage to the processor.

So to overcome this problem associated with voltage droops dropping too low below the voltage minimum or voltage spikes from rising up too high and exceeding the voltage maximum, some voltage regulators employ what's known as a droop function.

Now, all voltage regulators, as we've discussed, regulate voltage. Some of them will regulate voltage using that voltage feedback loop to compare the actual output voltage with a desired reference voltage. But the droop function is not simply the same as regulating voltage by using a voltage feedback loop.

The droop function is a technique that is designed to prevent voltage spikes from exceeding the predetermined maximum that can be supplied to a processor and prevent voltage droops from falling below the predetermined minimum voltage that can be supplied to the processor.

Now, I should point out that engineers use the term "droop" a little bit loosely, in two ways. In one way, "droop" refers to the unintentional drop in the voltage. The second meaning of "droop" is -- it refers to the intentional implementation of a droop function.

And when reading "droop" in light of the '944 patent,

every instance of the patent talks about the droop being related to the implementation of an intentional implementation of a droop function and not the unintentional drop in voltage when the processor goes from being in asleep state and demanding no current to being in an awake state, demanding a lot of current.

And so if we can turn to slide 39, we'll explain the technique of the droop function. And in the graph on the right-hand side of 39, let's assume that the processor is sleeping and the processor is not consuming a lot of current. Instead of the voltage regulator keeping the value of the output voltage at the midpoint between the minimum voltage, V min, and the maximum voltage, V max, the voltage regulator that employs the droop function while the processor is demanding very little current is going to raise the level of the voltage preemptively up to a higher level above the midpoint in anticipation of the processor subsequently waking up, demanding a lot of current, and there being a voltage droop.

And how does that prevent the voltage droop from falling below the minimum voltage level? Well, as shown in slide 40, when the processor wakes up and starts demanding a lot of current, there's a voltage droop as shown, which is an unintentional drop in voltage. But because the droop function increased the output voltage from the voltage regulator to a

higher level above the midpoint while the processor was sleeping, when the droop occurred, after the processor woke up, there's enough room for the droop to fall without falling below the minimum voltage level, V min, so the processor does not malfunction in that situation.

And as shown in slide 41, raising the level of the output voltage while the processor is sleeping to account for subsequent voltage drops, to keep them still above the voltage minimum, is known as providing additional legroom between that elevated value of V out and the minimum voltage, V min. So that's how the droop function prevents droops.

And so let's -- on slide 42, let's do a side-by-side comparison of a voltage regulator that does not have droop function, which is on left, and a voltage regulator that employs a droop function, which is on the right.

As shown on the left, when the load or the processor is sleeping and not demanding a lot of current, a voltage regulator without droop function is going to maintain the output voltage at the midpoint between V minimum and V maximum.

However, when the processor then suddenly wakes up and demands current, there's going to be a drop in the water pressure or a drop in the voltage so that the voltage droop is going to fall below V minimum and create a malfunction.

Now let's compare that with a processor that

implements a droop function and -- I'm sorry, a voltage regulator that implements a droop function. When a voltage regulator is implementing a droop function, it intentionally and preemptively raises the level of the output voltage to a higher value above the midpoint while the processor is sleeping so that when the processor subsequently wakes up and there is a voltage drop, there's enough legroom so that voltage drop does not fall below the minimum voltage level, V min, and the processor continues to operate properly.

Now, if we turn to slide 43, there's a little bit of an animation and an analogy, trying to analogize using the droop function to increase the output voltage in anticipation of subsequent voltage droops is like driving a car over a hill. Drivers want to keep the speed of the car, if they're a good driver, between a certain speed range, let's say between 50 miles an hour and 60 miles an hour.

However, as the car is approaching the hill, the car would ordinarily slow down as it's going up the hill. So in order to anticipate for the speed of the car slowing down as it approaches the hill, the driver will accelerate slightly so that as it goes up the hill and slows down, the speed is still going to be maintained within the range of acceptable speeds, between 50 miles per hour and 60 miles per hour.

So that was an explanation as to how voltage droops -- or the droop function prevents voltage drops or

droops from falling below the minimum. How does the droop function prevent voltage spikes from rising up above the maximum permitted voltage?

THE COURT: You know what? I think I understand this. It's going to be the opposite.

MR. ROWAN: Yes.

THE COURT: Let's kind of move through that, because you're going to run out of time, and I don't want to spend time on things that we don't need to.

MR. ROWAN: Okay.

THE COURT: So let's kind of get to the next part of the presentation.

MR. ROWAN: Okay.

So if I can --

THE COURT: I think it takes you around to 49 or so.

MR. ROWAN: Yes. So if we can maybe start at slide 50, Your Honor.

THE COURT: Sure.

MR. ROWAN: Thank you very much.

So as we previously explained for the droop function, it preemptively increases the output voltage when the current being demanded by the processor is low; and on the flip side, as Your Honor noted, the droop function will actually lower the output voltage when the processor is consuming a lot of current so that when the processor stops demanding current,

the voltage spike does not exceed the maximum.

So the droop function can be implemented using a droop feedback loop. The droop feedback loop is a different kind of feedback loop besides the voltage feedback loop and the current feedback loop. And the droop feedback loop receives information regarding how much current is being demanded by the processor, and it's going to help adjust the output voltage to either increase the output voltage when the processor is demanding a little current or decrease the output voltage when the processor is demanding a lot of current.

And so if we can go to slide 51, this shows the voltage regulator that we've been talking about that includes also a droop feedback loop. And as Your Honor can see on the screen, this -- I'm sorry. I think I have -- is my laser pointer working, Your Honor?

THE COURT: It is.

MR. ROWAN: Okay. Great.

So this voltage regulator has all types of feedback loops. It has the voltage feedback loop that we talked about, which, if you follow the laser pointer, goes to the error amplifier and then goes up to the pulse width modulator.

This voltage regulator also has a current feedback loop that we discussed, which begins with the current sense circuit and goes to the sense amplifier in the middle of the screen and goes up to the pulse width modulator in the upper

left of the screen.

And then it also has a droop feedback loop. And the droop feedback loop connects the current feedback loop to the voltage feedback loop, because the droop feedback loop uses the amount of current that's being supplied to the load to then try to adjust the voltage up or down, depending on whether the load is consuming a lot of current or a little current. And so the droop feedback loop includes the droop amplifier, as well as including the error circuit.

And I will go through this a little quickly, Your Honor, but as you can see, with the droop function, the current sense circuit shown in the upper right of the screen will measure the current being supplied to the load and output an initial measured current signal to the sense amplifier. That sense amplifier will then adjust that measured current signal to provide a final measured current signal. And that information about how much current is being supplied to the load now goes from the current feedback loop to the droop amplifier.

That droop amplifier will then adjust this current signal and supply the adjusted current signal to the error circuit, which is shown in brown in slide 52.

The error circuit will then take information from the voltage feedback loop. And based on the current information that it receives from the droop amplifier and ultimately from

the current feedback loop, this error circuit is going to add and offset to the voltage feedback in the feedback loop so that if the error circuit senses that there's being very little current that's being demanded by the processor, the processor is sleeping, the error circuit is going to add an offset so that the voltage regulator increases the output voltage to be higher than the midpoint, to account for voltage droops when the processor subsequently wakes up.

Alternatively, if the current information fed from the current feedback loop through the droop feedback loops droop amplifier indicates that there is a lot of current being demanded by the processor, the error circuit is going to incorporate and offset into the fed-back voltage to instruct the voltage regulator circuit to now lower the output voltage being supplied to the load below the midpoint, between V min and V max, so that when there is a subsequent voltage spike, there is enough headroom and that voltage spike does not rise above V max.

So I'm going to skip ahead a little bit.

THE COURT: Go back. I want you to finish explaining what happens next.

MR. ROWAN: Okay. So let's say -- let me take a step back, if I can, Your Honor. And let's say that there is very little current being supplied to the load. So the current sense circuit -- and I'm using my pointer here. The current

sense circuit is going to measure that very little current being supplied to the load, and it's going to output a corresponding measured current signal indicating there's very little current.

That measured current signal is going to be adjusted by the sense amplifier. And that measured current signal is then going to be sent to the droop feedback loop to the droop amplifier. The droop amplifier is also going to adjust that measured current signal. And the measured current signal is going to make its way to the brown error circuit.

The measured current signal is going to inform the error circuit that the amount of current being demanded by the load, by the processor, is very little. And in that scenario, the error circuit is then going to add an offset to the voltage -- if you see the highlighted pointer -- that's being fed back from the voltage feedback. That offset is going to be added to the fed-back voltage that's supplied to the error amplifier.

That offset is then going to be supplied from the error amplifier, as shown by the red line, to the pulse width modulator in gray, up at the upper left. And that offset is going to cause the pulse width modulator to control the circuitry and switches to then raise the output voltage that's being supplied to the load so that when the processor is demanding very little current, the voltage regulator is going

to increase the value of the output voltage supplied to the load, because when the processor subsequently wakes up and water flows through the faucet, there's going to be a voltage drop.

So what the voltage regulator does is when the processor is consuming very little current, it preemptively raises the output voltage supply to the load so that when the processor subsequently wakes up and there's a voltage drop, that drop doesn't fall below the minimum permitted voltage in the circuit.

And, Your Honor, that's shown in the slide, in slide 54. I don't know if I was too convoluted in my explanation, Your Honor, but if you have any questions about that --

THE COURT: No. Thank you.

MR. ROWAN: So in terms of -- we actually just walked through this a little bit, so I'm going to, if you don't mind -- so this is just a -- slide 57, it's just the converse, as Your Honor noted, that when the current -- when the measured current signal from the current feedback loop indicates there's a lot of current being demanded by the processor, that measured current signal is fed back to the droop feedback loop, through the droop amplifier, to the error circuit, so the error circuit knows that the processor is awake and consuming a lot of current.

The error circuit adds an offset to the fed-back

voltage in the voltage feedback loop, which propagates to the control circuitry, so that the control circuitry preemptively lowers the output voltage, as shown in the graph in slide 57, in anticipation of the processor suddenly going to sleep, the water faucet turning off, the water pressure increasing, which is analogous to the voltage creating a voltage increase spike, as shown in the figure. But since the voltage was preemptively lowered to a lower voltage, there is enough headroom or enough room to accommodate that voltage spike and still keep it below the maximum permitted voltage to be supplied to the processor.

So I'm going to skip over that a little bit.

So with that background, we've talked about voltage regulators in general. We've talked about voltage feedback loops, current feedback loops, the droop function being implemented by a droop feedback loop.

Let's turn to the '944 patent shown in slide 60. So as shown in slide 61, the '944 patent is entitled "Programmable Calibration Circuit for Power Supply Current Sensing and Droop Loss Compensation."

As we'll discuss in detail in a little bit, the alleged novelty of this patent is to perform current sensing and droop loss compensation based on temperature. When temperature changes, the circuit wants to be able to compensate for the current sensing circuitry and the droop

function.

So if we go to slide 62, here's Figure 1 of the '944 patent. Figure 1 of the '944 patent shows a voltage regulator that includes the three well-known feedback loops. It includes the voltage feedback loop, it includes the current feedback loop, and it includes a droop feedback loop.

And turning to slide 63, there will be a little bit of an animation, Your Honor. If we talk about what the voltage feedback loop is, you can see the voltage regulator supplies an output voltage, shown by the red line, to the load. That output voltage is fed back via the voltage feedback loop to the error amplifier, which is now shown in red.

The error amplifier compares the actual output voltage in red with the desired target reference voltage in green. It creates an error signal. That is supplied to the PWM or pulse width modulator, which, as we discussed in some of the prior examples, will control that circuitry to bring the actual output voltage in line with the desired target reference voltage.

The '944 patent also includes a current feedback loop. The current feedback loop, as shown in slide 64, includes the current sense circuitry in brown. The current sense circuitry will measure the current being demanded by the load or demanded by the processor and will supply that initial

measured current signal to the sense amplifier shown in the yellow triangle.

That sense amplifier in the yellow triangle will then adjust that measured current signal to produce a final measured current signal, apply it to the gray PWM in slide 64, which in turn will control the circuitry in blue so the regulator can make adjustments.

THE COURT: Tell me what you believe the amplifiers do, whether it's the error amplifier or an adjustable sense amplifier or a droop amplifier. What is the function of an amplifier?

MR. ROWAN: So let me start off sort of with the first concept, and then I'll explain in a moment a later concept that's implemented by the '944 patent.

The amplifier, as its name implies, amplifies the signal. So if you have the measured current signal coming from the current sense circuitry to the amplifier, you can think of the amplifier, at a high level, as a multiplier.

So let's say that the measured current signal coming from the brown current sense circuitry shown in slide 64, let's say that signal has a value of 2. And let's say the amplifier is designed to multiply the magnitude of that signal of 2 by a factor of 10.

So if the measured current signal from the current sense circuitry input to the sense amplifier is 2, the

amplifier will multiple that by 10 and output a final current measured signal of 20.

THE COURT: And is that because it makes it easier for the PW something to read?

MR. ROWAN: Yeah. So it brings -- one function is it will bring the signal level up to a level that can be handled and appreciated by the PWM --

THE COURT: PWM.

MR. ROWAN: -- for it to do its function.

THE COURT: Okay.

MR. ROWAN: That's exactly right.

Now --

THE COURT: But the amplifier itself, other than amplifying, isn't performing any other function? It's not adjusting current or --

MR. ROWAN: Well, it actually is, Your Honor.

THE COURT: Okay.

MR. ROWAN: So if you see -- on slide 64, you see the yellow line going into the amplifier and the yellow line going out of the amplifier?

THE COURT: I do.

MR. ROWAN: There is also another black line that is shown going into the amplifier, at the bottom of the amplifier. Can you see that, Your Honor?

THE COURT: Yes.

MR. ROWAN: If you trace that black line down, that black line goes to the calibration control circuit at the bottom left-hand portion of Figure 1. What that black line going to the sense amplifier is, that is a sense output, as described in the patent. And that sense output is actually going to adjust the operation of the sense amplifier.

And I'll pause there. If you'd like me to move on, Your Honor, I'm happy to do so or I'll pause.

THE COURT: It looks like the information is coming from the calibration control circuit to the amplifier. Is that the line you're referring to?

MR. ROWAN: That is exactly right. So there is a line that comes from the calibration control circuit at the bottom.

And, Your Honor, let me use my pointer. Do you see the pointer on the screen?

THE COURT: Yes.

MR. ROWAN: The sense output comes up and it goes into the adjustable sense amplifier. And that's going to change the way the adjustable sense amplifier operates.

So before, the sense amplifier was multiplying the initial current value of 2 by a factor of 10 to output a final measured current signal of 20. What this sense output will do, if you change the sense output, the sense output is going to change the magnitude by which the sense amplifier

multiplies that initial current signal from the current sense circuitry.

So let's say in one situation the sense amplifier instructs -- I'm sorry, the sense output instructs the sense amplifier to multiply by a factor of 10. The initial measured current signal comes in at 2. The amplifier multiplies it by a factor of 10 and outputs the final measured current signal of 20.

Now, as we'll get into, as the temperature changes, the sense output value is going to change. So what the calibration control circuit will do at a different temperature, it may output a sense output to the sense amplifier at a different temperature to cause the sense amplifier to not multiply the measured current signal from the current sense circuit by a factor of 10, but at a different temperature the sense output may instruct the sense amplifier to multiply that measured current signal of 2 by a factor of 11 and then output a final measured current signal of 22.

So as temperature changes, the sense output is going to change. That sense output is going to adjust how much that sense amplifier multiplies the initial measured current signal by to output a corrected final measured current signal to the gray PWM.

So at one temperature, the sense amplifier may multiply the initial current measured signal of 2 by a factor

of 10 to output a final measured current signal of 20. In another situation, at a different temperature, the sense output may cause the sense amplifier to multiply that initial current measured signal of 2 by a factor of 11 to output a corrected measurement to the PWM, and that corrected measurement being 2 times 11, 22.

So collectively, the current sense circuit and the sense amplifier work together to adjust and measure the true current being supplied to the load, based on changes in temperature. And that occurs by changing -- the calibration control circuit changing the value of the sense output based on temperature to change the operation of the yellow sense amplifier.

THE COURT: Is the information that's coming from the calibration control circuit -- you're using the term "sense output" to say that's the information that's coming out of the calibration control circuit.

MR. ROWAN: Correct.

So the patent describes that this output, as shown in the highlight on the screen --

THE COURT: Yes.

MR. ROWAN: The patent describes that output that goes from the calibration control circuit to the yellow adjustable sense amplifier as being the sense output.

THE COURT: Okay.

MR. ROWAN: Similarly, if we can look at the highlighting as well, the droop output is the output that the calibration control circuit outputs, as shown by the highlighting, that goes to the adjustable droop amplifier.

So the sense output can adjust the sense amplifier to correct and adjust the measurements of current being supplied to the load. The droop output does the same thing to the droop amplifier. It will change how much the droop amplifier amplifies or multiplies that signal that comes into its input.

And so as temperature changes, that droop output is going to tell the droop amplifier, multiply by a factor of 3, multiply by a factor of 4, so it can adjust the droop function that's being implemented by that droop feedback loop based on temperature.

THE COURT: All right. So getting back to my original question, which is what do amplifiers do, and your response is amplifiers convey information, in this case it looks like -- I don't know if they always end up with the PWM.

MR. ROWAN: So if you take an amplifier -- let's leave the amplifier out of this context and talk about it in a vacuum, if that's okay, Your Honor.

THE COURT: Sure.

MR. ROWAN: There are two types of amplifiers. There is an adjustable amplifier, and then there's an amplifier that

is not adjustable.

If you have an amplifier that is not adjustable, it has a fixed multiplier in it. It multiplies everything by a factor of 10 no matter what. So whatever signal is input, if you put in a signal of 3, that amplifier is going to multiply it by a factor of 10 and output 30. If you input 4, that amplifier is going to multiply it by a factor of 10 and output 40. That is one type of amplifier.

What's being used here is called an adjustable amplifier. So you can see in Figure 1, the sense amplifier actually -- and I know the type is small. It refers to it as an adjustable sense amplifier.

The droop amplifier likewise is referred to as an adjustable droop amplifier. Those have a slightly different function. The amplifier multiplies the input signal by a factor, but the adjustability of those, it can be adjusted so that you can actually change the factor by which the amplifier multiplies it by changing the input to the bottom of amplifier.

So the adjustable amplifier, under one set of circumstances, may input 3; the control signal may say multiply that by 10, so it outputs 30. In the next instance the amplifier may input 3. The control signal to the amplifier says multiply it by 11. So it doesn't output 30 anymore; it outputs 33.

THE COURT: Thank you.

MR. ROWAN: And so -- let me just get my bearings a little bit, Your Honor. I apologize.

THE COURT: That's okay. I throw people off all the time.

MR. ROWAN: So if you turn to slide 65, the '944 patent talks about the droop function in column 1, lines 36 to 41. And this droop function, as shown, it says that the droop function "automatically lowers the output voltage based on the output current" and "This provides more headroom in the case of load transients."

And that's described in the graph at the bottom of the slide. So in the bottom of the slide, when the processor is awake and consuming a lot of current, the droop function will lower the output current -- or lower the output voltage to a lower level below the midpoint, based on the demand for the output current.

And what that does is that provides more headroom. That provides more space between the level of the output voltage that's been lowered and the maximum voltage, V max, so that when the processor subsequently goes to sleep and there is a voltage spike or increase, there's more headroom to accommodate that voltage transient or the voltage spike, so that the voltage spike does not go above the maximum voltage, V max.

Also, as shown on the next slide, on slide 66, the droop function also sets the voltage higher when the processor is sleeping and thereby adjusts the drop loss, as shown in the slide.

So as quoted in column 8, lines 64 to 67, it says that the "adjustable droop amplifier" -- which we're talking about -- "may be used to adjust the droop loss."

And so if you see in the slide, on the left-hand side there are two graphs. There is one graph that begins with a purple line and then falls into a red line and another graph that begins with a purple line and falls into a green line. The graph that has purple and red is the voltage regulated without the droop function. The voltage regulator tries to keep that voltage, output voltage, at the midpoint between V max and V min. And, therefore, the starting point for the droop loss, the voltage drop, is lower, and the corresponding droop loss goes below the threshold of V min as shown by the red line.

Alternatively, by adjusting the starting point of the droop loss up, that's shown by the green line in the graph. And when there is a subsequent voltage drop, that voltage drop does not fall below the minimum voltage, V min.

Your Honor, I'd like to skip over, because I know I'm running short on time, if that's okay, unless you have any questions thus far.

THE COURT: No. Keep going.

MR. ROWAN: Okay. I'd like to skip forward to slide 87.

And I'm sorry. My remote control is slower than I am.

Okay. So let's walk through an example.

Sorry. I'm going to back up to slide -- I'm going to back up to slide 82, if that's okay, Your Honor.

THE COURT: Sure.

MR. ROWAN: And 82, what I'd like to do is show the language of the claim and how that corresponds to the various things in Figure 1 of the '944 patent.

So Claim 1 is the only independent claim in the '944 patent. And as shown in Claim 1, the highlighted portion says that the "calibration control circuit interfaces with said temperature input to receive temperature data."

As you can see in Figure 1 on the right-hand side of the slide, there's a temperature sensor in light blue, and that receives -- that senses the temperature of the voltage regulator components and will output corresponding temperature data via the blue line to the dark blue calibration control circuit.

Then if you go to slide 83, the highlighted portion of the claim states that the "calibration control circuit interfaces with the regulator circuit via said sense outputs,

said droop outputs, and said load voltage input."

So if we take a look at the annotated Figure 1 on the right-hand side, the sense output, as we were discussing, Your Honor, is shown by the yellow line that goes from the blue calibration control circuit to the yellow adjustable sense amplifier represented by the triangle. The droop outputs are shown by the pink line that go from the blue calibration control circuit up to the pink adjustable droop amplifier. And the purple line represents the load voltage input that is supplied from the load via the purple line to the blue calibration control circuit.

And that is basically -- that load voltage input supplies the actual output voltage that's being applied to the load. And so as you can see, that line goes down all the way back to the calibration control circuit so the calibration control circuit can take that into account when it's doing its calibration.

If we move to slide 84, the claim states that the temperature data is used by the calibration control circuit to adjust the sense outputs and the droop outputs. And so as you can see, in light blue the temperature sensor senses temperature, provides temperature data to the calibration control circuit via the blue line. The calibration control circuit will then analyze that temperature data, and it will change the yellow sense outputs going to the yellow sense

amplifier and will change the pink droop outputs being sent to the pink droop amplifier based on the temperature.

Moving on to slide 85, the highlighted language states that the calibration control circuit will interface with nonvolatile memory to store calibration data.

Now, the calibration data is the data in the blue calibration control circuit that will relate the temperature to the sense and droop outputs that are supplied to the sense and droop amplifier.

So if the temperature is 52 degrees Celsius, which is pretty high -- it's about 126 degrees Fahrenheit -- at that temperature the calibration control circuit is going to send certain values of the sense output and another value of the droop output to the droop and sense amplifiers so that the current measurement circuitry can be corrected based on that temperature of 52 degrees Celsius, and the droop function that's implemented by the droop amplifier can be corrected to be accurate at that temperature of 52 degrees.

If the temperature then drops to 35 degrees Celsius, the temperature sensor in light blue is going to send that temperature data to the calibration control circuit. That calibration control circuit is then going to output different sense output and a different droop output to the sense and droop amplifiers so that the sense amplifier will adjust the current measured circuitry based on that temperature, and the

droop amplifier will adjust the droop function based on that as well.

And this calibration control data is stored in nonvolatile memory, as shown by the highlighted language of Claim 1.

So, Your Honor, I'm going to pause there. It's a good breaking point. I might have been a little bit selfish with my time and run over. But unless Your Honor has any questions, I think I'll stop there.

THE COURT: All right. Thank you.

MR. ROWAN: Thank you very much.

THE COURT: I probably have questions. I just haven't thought of them yet.

Thank you.

Dr. Sarrafzadeh, do you have any response to anything you heard from the defense expert?

DR. SARRAFZADEH: I would, if I could have a couple of minutes.

THE COURT: Sure. Take your time.

DR. SARRAFZADEH: I appreciate that.

THE COURT: Absolutely.

And, really, what I'm looking for is where you disagree and why.

DR. SARRAFZADEH: Sure. Thank you, Your Honor. I appreciate the opportunity.

When I started learning about patents about 30 years ago, I learned that you got to look at a claim and interpret the claim terms.

If you look at this slide that I highlighted before, it talks about a regulator circuit block in the preamble. It talks about the calibration control circuit in the preamble. And the regulator could obviously contain both the regulator circuit block and calibration control circuit.

And what Claim 1 talks about is how these two interface and how the calibration control circuit interfaces with the temperature input block.

What I heard in the tutorial preceding me is not that. The tutorial started looking at details of Figure 1 -- if you could go to the next slide, please -- and started interpreting what is in Claim 26 as being Claim 1. That's not what is going on.

What I heard here was -- it was stated that '944 contains voltage feedback loop.

Go to the previous slide, please.

Here I do not see any feedback loop. This is Claim 1. There are many ways of implementing the regulator circuit block. I do not see any voltage feedback loop.

In the previous tutorial I heard that '944 contains current feedback loop. First of all, what does it even mean to say '944 has this or doesn't have this? We need to talk

about a claim, Claim 1 maybe. Claim 1 doesn't show any feedback loop. It's just a block. That's what Claim 1 talks about.

It was also stated that the temperature sensor gives information to calibration control circuit. Again, in Claim 1, there is no temperature sensor. In my tutorial, I showed there are specific claims that talks about the temperature sensor. We cannot read that into Claim 1.

It was also stated, mistakenly, that anywhere in the patent when there is a discussion of droop, they are implementing droop function. Nowhere in Claim 1 I see there and read the word "droop function." So that's incorrect.

So I fundamentally disagree with the number of claims made, in particular trying to read -- again, if we could go to the next slide -- the details of what is in the regulator circuit block into Claim 1. It's not.

At best, Claim 26 is talking about adjustable droop amplifier and all that, not Claim 1. In fact, I have shown in my tutorial alternative design where an adjustable droop amplifier is missing. This is Figure 8 of provisional.

So I do disagree, respectfully, with a number of comments made, but more specifically about taking Figure 1 and imagining that '944 patent is Claim 1. It's not.

This, what is shown here in front of you, that's Claim 1. It does not talk about what is inside calibration

control circuit. It does not talk about what is inside temperature input block. And, more specifically and very important, where the tutorial was built on, it does not talk about any of the details of what is inside the regulator circuit block. There are no loops, there are no amplifiers that is discussed in Claim 1.

So this is my fundamental disagreement, but there are a number of detailed ones that will take too long to go over.

THE COURT: Do you have any disagreement with the description about what the different components do and how they function?

DR. SARRAFZADEH: Well, different components, as it is stated in Claim 26, the general functionality of what PWM does, that's fine. But that's not stated in Claim 1.

What an amplifier --

THE COURT: Yeah, that's a different discussion. I get that. We're going to hear all about that tomorrow, over and over again.

I'm not there yet. I just want to make sure that I understand kind of the way the different things in this particular patent work.

DR. SARRAFZADEH: Some of the detailed circuits -- for example, amplifier and error amplifier that is in Claim 26 -- it seems more or less they are discussed and explained properly, for the most part.

THE COURT: Okay. And I guess one of the places where I thought I heard a difference -- and it could just be my ignorance regarding electronics -- is that I thought in your description and in answer to my question, that you were telling me that the amplifiers actually change things, that they -- well, by comparison, as I understood from the defense expert, the amplifiers are providing information. As I understood from my conversation with you, no, the amplifiers are actually changing things; there's a function, that they're changing things. And I may have misunderstood you as compared to what they were telling me.

DR. SARRAFZADEH: Right. I think what they did is they put all the amplifiers under the same umbrella.

So what I was discussing in my tutorial is an operational amplifier, which is block 180, which is an adjustable droop -- I'm sorry. It's block 175, which is an error amplifier.

THE COURT: Slow down. Is that on this diagram?

DR. SARRAFZADEH: It is on that, sort of in the middle, the triangle, going from right to left.

THE COURT: The adjustable droop amplifier?

DR. SARRAFZADEH: No. The one kind of below it, an error amplifier.

THE COURT: I see it.

Okay. Thank you.

DR. SARRAFZADEH: So what that does is takes the reference voltage, the desired voltage, 5, and it takes the voltage that it is reading from the system, and through a feedback loop makes sure that the voltage that gets delivered to the load is the same or very similar to the reference voltage. So it does a differencing, whereas the amplifier that you see way on top, 150, through a gain that comes from calibration control circuit, you can adjust the gain and send the higher value there.

So you heard, I think, both of us correctly. But each of them have a different function.

THE COURT: Okay.

DR. SARRAFZADEH: And that needs to be very clear. That's fundamental to understanding Claim 26, not Claim 1, and Figure 1.

THE COURT: Okay.

What information does the calibration control circuit use in order to adjust whatever it ends up adjusting?

DR. SARRAFZADEH: Sure.

Previous slide, if you don't mind.

So that's dictated in Claim 1. It says you get the load voltage input from the regulator circuit block. It receives a temperature input from the temperature input block. And Claim 1 is open to what they could be. It's just where they are coming from.

Then the calibration control circuit, which inside of it is a little microprocessor or a controller or finite-state machine as we call it, it goes through computation, it writes things into local volatile memory, and gives information back to the regulator circuit block in terms of what to do with the current, what to do with the voltage. That's the limit of Claim 1.

THE COURT: And in looking at Figure 1, where it shows the things that the calibration control circuit is taking into consideration, does it also take into consideration information from the memory?

DR. SARRAFZADEH: Yes. So one of the -- the very first thing of the first claim elements says said nonvolatile memory stores calibration data. That's not shown in this figure, but that is in Claim 1, yes.

Remember, during the manufacturing, you program the device to know what went wrong in manufacturing. Calibration control circuit now takes that information and other things -- temperature and load voltage input -- and dictates to the regulator circuit block what to do with current and voltage.

THE COURT: Okay. Thank you.

Is there anything else you want to share with me at this time?

DR. SARRAFZADEH: There are a number of details, but

this is a fundamental misunderstanding, it seems, between myself, at least, and the other side.

THE COURT: All right.

DR. SARRAFZADEH: Claim 1 is not Figure 1.

THE COURT: All right. Thank you.

DR. SARRAFZADEH: My pleasure.

THE COURT: Would you like to respond?

MR. ROWAN: Yes.

If you don't mind keeping up this figure here, please --

THE COURT: Not at all.

MR. ROWAN: And so, Judge, just very briefly, because I know there is going to be a lot of talk, as Your Honor noted, about this tomorrow, what I was trying to do was give some background of how Figure 1 operated and what the disclosure of the '944 patent specification was all about so that Your Honor -- to assist Your Honor to help interpret the claims as they should be in light of the specification.

As shown in slide 55 up on the screen, what the plaintiffs are doing is they're masking everything that is in Figure 1 to avoid what is actually going on.

If you take a look at the claim, the claim requires sense outputs, the claim requires droop outputs. Based on the Figure 1 that's shown on the screen that's masked, those outputs are just outputs. There's no meaning given to what

"droop" means or "sense" means in the terms "sense outputs" or "droop outputs" in the claim.

One other thing that I would like to point out, I do have some disagreements with plaintiff's tutorial, but there is one thing that I just wanted to highlight. And it may be a slight -- it may be a slight misunderstanding, but if we can pull up slide 22 of plaintiff's tutorial.

So on slide 22 of plaintiff's tutorial, note that the slide talks about a droop function, and it talks about automatically lowering the output voltage based on output current. That is what the droop function does.

However, Your Honor, what is actually shown in the graph on the right-hand side is just a regular voltage regulation. The voltage regulator wants to keep the output voltage at a midpoint when the processor is sleeping in the first part of the graph.

When the processor wakes up, that voltage then dips and then it comes back up to the midpoint while it's awake.

And then if you travel to the right on the graph, when the processor goes back to sleep, that voltage will then spike and then come back to the midpoint.

So this is showing a regular voltage regulation, where the voltage regulator is always trying to bring that output voltage back to the midpoint. It is showing a voltage regulator without a droop function.

And this figure looks a lot like a figure on Wikipedia -- if we can pull that up -- and I'm not sure if that's where the plaintiffs got this figure, but if we can put the two figures side by side and blow it up, you can compare the wave form on the left-hand side. Although they seem to imply that that relates to a droop function, this is really a voltage regulator without a droop function.

And then if you take a look at Wikipedia on the right-hand side, that talks about, at the very first line, in a regulator not employing droop. So that is a very similar wave form.

So just to avoid any confusion with Your Honor, this mention of a droop function in slide 22, that is not the corresponding wave form that slide 22 is showing, the droop function.

As we know, what the droop function does is when the processor is consuming low current, the voltage regulator preemptively lowers the output voltage to account for a voltage spike. When the processor is consuming a lot of current -- or consuming very little current, it will raise the output voltage to accommodate a subsequent voltage droop.

So that is one -- one disagreement that I have with the tutorial. I'm not sure if it's intentional or not, Your Honor, but I just wanted to address that.

THE COURT: Thank you.

Do you have any comment or disagreement about what a droop function is or what droop is?

DR. SARRAFZADEH: Yes, I do.

As I was explaining, the figure on the right is the figure from the previous slide where I discussed droop loss compensation. And on this slide, I said let's compare droop loss compensation with droop function. So the right is a different thing; left is a different thing.

The figure on the right was not supposed to be a picture of droop function, totally agree with that. But the idea here was to contrast the two. But the fact that droop function is what automatically lowers the output voltage based on the output current, that's a fact. We teach that every day to our student, no disagreement there.

THE COURT: Okay.

DR. SARRAFZADEH: And the fact that droop function is nowhere in Claim 1, that's a fact, no argument there.

THE COURT: Okay. All right. Thank you.

DR. SARRAFZADEH: My pleasure.

THE COURT: I think that's everything for today.

We're going to get back together -- is it tomorrow afternoon when we get back together or tomorrow morning?

MR. CLOSE: Tomorrow morning, Your Honor, at 9:00, I understand.

THE COURT: All right. Unless there's anything else,

I think that's all for today. I'll see you all tomorrow at 9:00.

Thank you very much.

COUNSEL: Thank you, Your Honor.

(Proceedings concluded.)

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I certify, by signing below, that the foregoing is a correct transcript of the record of proceedings in the above-titled cause. A transcript without an original signature, conformed signature or digitally signed signature is not certified.

/s/ Nancy M. Walker *7-15-19*

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